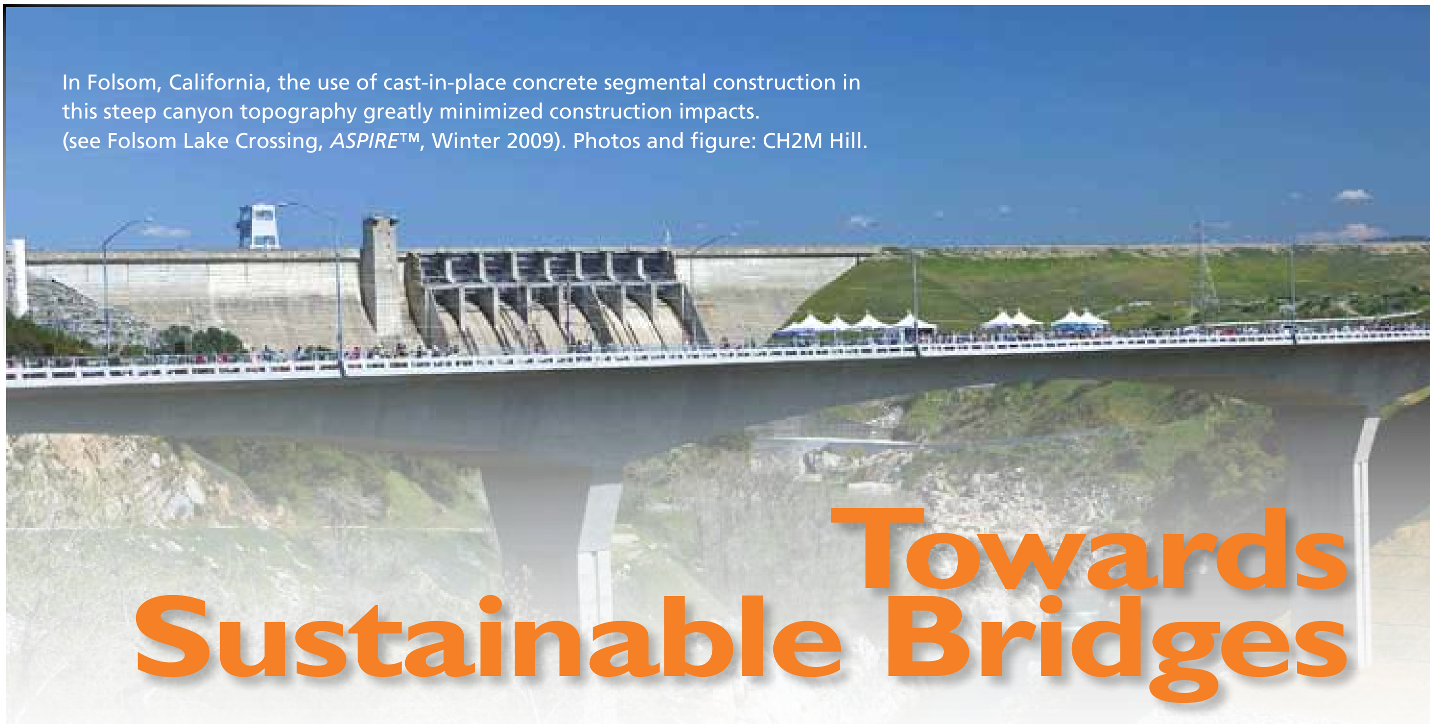
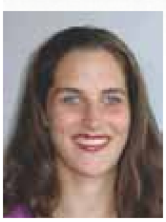


In Folsom, California, the use of cast-in-place concrete segmental construction in this steep canyon topography greatly minimized construction impacts. (see Folsom Lake Crossing, *ASPIRE*™, Winter 2009). Photos and figure: CH2M Hill.

Towards Sustainable Bridges



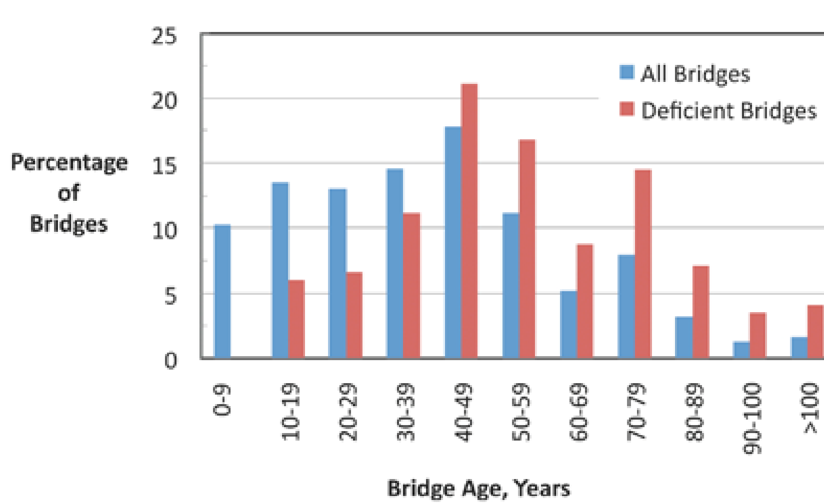
by Jeralee L. Anderson, University of Washington and Joe Showers, CH2M Hill

Bridges are a critical component of our national highway infrastructure. The phenomenal replacement cost of our aging national inventory of approximately 600,000 highway bridges is estimated to be on the order of one trillion dollars. These structures, which are the backbone of our national highway system, have seen increased traffic volumes and environmental exposures that were not imagined during their original design and many have surpassed their expected service lives. As a result, approximately one quarter of the national bridge inventory is currently classified as "structurally deficient" or "functionally obsolete." The increasing backlog of deficient bridges raises the daunting prospect of a major ongoing bridge repair, reconstruction, and replacement program that could extend far into the future. Faced with this problem, it is clear that the strategies of meeting lowest initial construction cost and only addressing operational requirements may no longer be the best approach for constructing a sustainable bridge infrastructure that will be a legacy we leave for subsequent generations.

Current bridge design and construction practice has evolved over time in response to many different challenges and changing standards, and the incorporation of new sustainability principles in practice will see a similar process. Unfortunately, there are no "silver bullets" to address contemporary issues like lack of project financing, increasing cost of energy, and limited key resources. These are complex problems that will result in an evolution in how we design, build, and operate bridges. So what can do we do now to develop a sustainable bridge infrastructure?

Strategies for Change

The good news is that sustainability is not difficult to implement. Many strategies exist that, when combined, can effectively and successfully achieve a more sustainable bridge as an end product. Approaching bridge design and construction with a different angle—one that uses a holistic (systems-thinking) perspective—can do more for the environment and society than simply



Percentages of the bridge inventory in the United States that fall within various age categories.

designing to meet basic functional criteria and environmental compliance.

Importantly, a life-cycle perspective must be used in the selection of materials, design details, and to define service life, maintenance criteria, and end-of-life requirements for every bridge. This can be done by using service life prediction models, life-cycle cost software, life-cycle assessment tools, and sustainability metrics like "Greenroads." These decision-making tools can evaluate environmental impacts upstream and downstream in the materials supply chain and analyze long-term, life-cycle costs.

For example, much of our domestic steel reinforcement production uses recycled scrap as opposed to virgin materials. There are also numerous opportunities to recycle concrete aggregates and other common construction materials. A life-cycle assessment would indicate that these recycled material choices have several sustainability benefits, including reduced energy consumption and the overall construction environmental footprint for water and air emissions. A life-cycle cost analysis would also show that these choices would likely reduce long-term costs as well. Life-cycle-based thinking offers a broader perspective that is based on thinking in terms of larger systems, and is better able to address more complex interrelationships than focused, reductionist design of parts and components of the bridge alone.

More than Recycling

Note that sustainability is more than simply recycling. There are many opportunities for bridge designers to minimize use of non-renewable energy in the design and construction process. For instance, considering implications for traffic delays and on-site equipment usage can ultimately reduce driver fuel costs, delays, contractor fuel costs, and worker exposure to unhealthy emissions. Similarly, alternative or rapid construction methods can also save time and emissions. On-site fuels could even be replaced with biofuels or hybrid equipment engines.

Also, different approaches such as adaptive bridge design, design for deconstruction, or some structure reuse strategies can help preempt costly problems and rehabilitations due to natural hazards, climate change, and human behavior. Vehicle technology and transportation modal access can vary over the anticipated bridge life span. Providing the flexibility to accommodate changes in load capacity or deck geometry, pedestrian or bicycle traffic, or transit services is often an effective sustainable solution that also provides a robust, socially useful, and beneficial bridge. Additionally, designers can minimize long-term construction footprint impacts by considering the use of longer spans or more compact foundation systems, reusing original bridge footings for replacement projects, including prefabricated elements that are easy to deconstruct, or even building abutments that can be used for multiple types of bridges.

For the Fort Edmonton Footbridge in Edmonton, Alberta, Canada, a post-tensioned, precast segmental concrete deck system was selected for the suspended superstructure, to minimize field erection time and to provide for improved construction quality and long-term durability.

Additional Key Components

Two key components of more sustainable bridge construction practice are quality control and long-term performance monitoring. High, yet achievable, quality standards for bridge contractors provide the public stakeholders and owner-agencies insurance for an extended service life, and minimized future maintenance and repair needs. Beyond initial construction, though, performance should continue to be tracked regularly to preempt costly safety problems or catastrophic failures. There are a number of nondestructive testing technologies currently available that allow noninvasive investigation of bridge structural components. (see also "Advances in Nondestructive Evaluation and Structural Health Monitoring of Bridges," beginning on page 47).

Finally, think beyond satisfying only operational requirements. Humans are not the only end-users of the bridges. These large-scale structures can become habitat for and influence the behavior of other species beyond construction through their entire service life. Furthermore, bridges also have aesthetic and cultural value that extends beyond meeting functional needs. Bridges are among the most visually prominent objects within their surrounding environments and some of these structures will endure as an icon in their surrounding communities for future generations.

The Paradigm is Shifting

Decisions that we make today in managing our nation's 3.7 billion ft^2 bridge deck inventory have implications which extend far into the future. Sustainability is not difficult to manage, and the market is ripe for change. However, sustainability may challenge many of our basic ideas of what is a good and practical bridge design and encourages us to go beyond this existing knowledge. Often, it forces us to combine new and old ideas, or find innovative ways to make bridges better. This innovation starts with small choices made on everyday bridge projects by everyday bridge engineers and contractors. Ultimately, these choices will help shape bridge design, construction, and operation practice to be more sustainable for the benefit of ecosystems, economies, and people.

The Aurora Avenue Bridge in Shoreline, Wash. incorporates public art into the concrete walls to enhance the aesthetic appeal of the bridge approaches.